a guide to

# CREATING VERNAL PONDS

all the information you need to
build and maintain an ephemeral wetland

Thomas R. Biebighauser

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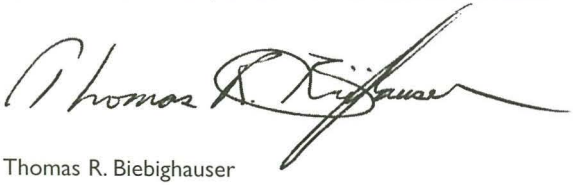

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Cover photo shows the aquatic plant sweet flag surrounding a vernal pond constructed in Menifee County, Kentucky, 5 years ago.

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## About this Guide

*Melting snow fills a constructed vernal pond.*

The techniques described in this publication have been used successfully in Kentucky, Ohio, and Minnesota. They draw from basic pond building principles and are coupled with the concepts of vernal pond ecology. The full geographic application of this guide is undetermined, however it is anticipated that the techniques offered are suitable for vernal pond construction in the eastern, southern, and mid-western United States. This guide is designed to help the reader think through site selection and the construction process in creating a vernal pond that looks and functions like a natural wetland.

This guide stresses the importance of maintaining and protecting natural wetlands. It also provides the reader with clues for identifying wetlands during the dry season. The techniques provided in this guide may be used by a variety of individuals from the suburban homeowner to the educator, the public land steward, and the private landowner. It is the intent of this guide to assist and inspire individuals to select an appropriate location and to successfully build a vernal pond in their area.

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# About Vernal Ponds

Vernal ponds are a type of seasonal or temporary wetland. They were once common, naturally occurring features on the landscape. The scouring process resulting from the ebb and flow of flooding rivers, lakes, and oceans created many vernal ponds. Others developed through wind action, earthquakes, falling trees, fire, and chemical actions in the soil. In most cases they are shallow, temporary, and separated from streams and rivers. This often made them tempting candidates for draining or filling. By nature of their ability to hold water, many were deepened and are now managed as permanent ponds and lakes.

Vernal ponds are known by many names and vary in definition. In some locations their name denotes the relationship to the vernal or spring equinox. In areas where the seasons are less pronounced, many refer to them as ephemeral, seasonal, or temporary wetlands. Regardless of the name, the defining characteristics are that they periodically dry up and do not contain fish. Drying may occur annually or only in drought years. In general they dry most often in late summer or early fall; however, heavy rains may fill them any time of year.

In recent years society has begun to appreciate the ecology of vernal ponds and seasonal wetlands. It is the temporary aspect of these wetlands that makes them so important. The wet-dry cycle prevents fish from becoming established, allowing critical breeding and rearing habitat for amphibians, crustaceans, and insects. Vernal ponds and other seasonal wetlands provide a window of necessity for these species to function and fulfill their role in the ecosystem.

*Seasonal wetlands are important for the survival of certain dragonfly species.*

Another characteristic of vernal ponds is that the soil on the bottom is often quite firm. Periodic drying allows leaves and dead plants that have accumulated in the wetland to decompose, making it much easier to walk in than a wetland that contains water all year. There may also be indicator aquatic plants such as cattails, bulrushes, and sedges that thrive in their static or non-flowing water.

*Two-year-old vernal pond in fall.*

*Two-year-old vernal pond in winter.*

*Two-year-old vernal pond in spring.*

## a vanishing feature

For a variety of reasons vernal ponds are not as common as they once were and the possibility of restoring them in the exact location where they once occurred may be limited in most areas. Their temporary nature has not provided them the consistent legal protection often afforded permanent water wetlands. Many natural vernal pond wetlands have been claimed by society and are now covered by expensive infrastructure such as roads, buildings, and parking lots. Fortunately, we can re-establish vernal ponds that look and function like their natural counterparts. By applying basic site selection skills, we can place these new wetlands in the same general area that they once occurred, restoring an important component of the landscape.

Incentives to restore or establish seasonal wetlands are plentiful - to prevent flooding by holding rainwater; to have a place to wade with the tadpoles, or to hear the melody of spring peepers and the chorus frogs on a spring night. Replacing this vanishing part of our landscape is as rewarding to us as it is essential to the health of the environment.

## habitat for common & uncommon wildlife

Wetlands that do not contain fish are uncommon. In North America, approximately one-half of all frogs and one-third of all salamander species rely on seasonal or temporary wetlands for development. Wood frog, spotted salamander, and eastern spadefoot toad larvae are just a few of the amphibians that can successfully mature and emerge from these fishless habitats. Vernal ponds are less likely than permanent water ponds to contain saprolegnia, a fungus that is detrimental to frog, toad, and salamander eggs. Vernal ponds also have low numbers of eastern newts that prey heavily on amphibian eggs and larvae.

*Many amphibians such as this spotted salamander depend on seasonal wetlands.*

*The federally endangered Indiana bat, along with nine other bat species, use vernal ponds located on ridge tops in eastern Kentucky. (John MacGregor photo)*

Waterfowl such as the wood duck and mallard use vernal ponds extensively during migration, consuming insects, crustaceans, and seeds for energy during their long flights. Shorebirds, such as the spotted sandpiper and lesser yellowlegs, search out and feed on exposed mud flats that are created as water levels drop. Reptiles such as the eastern box turtle and the eastern garter snake also use vernal ponds, often as feeding stations as they move from one area to another. Mammals use vernal ponds too. Bats are attracted to them as a water source and to the insects that fly over the water.

## watershed protection

Vernal ponds help protect watersheds. They capture and hold water, allowing time for it to seep into the surface and recharge groundwater supplies. This reduces the amount of water runoff, lessening erosion and downstream flooding. Vernal ponds also capture sediment, thereby protecting water quality in streams and rivers.

## education

A vernal pond makes an excellent outdoor classroom, offering learning experiences from design and construction to full restoration phase. Vernal ponds are generally easily accessed, allowing students to collect eggs and tadpoles from frogs, toads, and salamanders. An evening visit often produces a rich chorus of frog and toad calls, providing opportunities for sound identification studies. Several curriculums may be established around the development of a vernal pond, allowing students to track plant and animal life in different seasons. A list of teaching aids is found in Chapter 4.

*One scoop with a dip net may yield dragonfly larvae, daphnia, water boatmen, and isopods. (Evelyn Morgan photo)*

## mosquitoes

Mosquito larvae may be found in vernal ponds, developing from eggs to adults in less than a week in warm weather. Salamander, dragonfly, and damselfly larvae, along with many predatory insects such as the water strider and backswimmer, eat mosquito larvae. Dragonflies and swallows patrol the daytime sky over vernal ponds, preying heavily on adult mosquitoes. Bats frequent the night sky over vernal ponds, also feeding on mosquitoes and other flying insects. One rarely encounters adult mosquitoes near vernal ponds in eastern Kentucky; their numbers are kept in check by all the species that use them for food.

*Visiting a vernal pond can be an exciting environmental education field trip.*

# chapter two

# Planning a Vernal Pond Construction Project

Regardless of the project, planning is always a critical step. Chapter 2 will lead you through the basic principles of understanding a local environment, its functions, and how those functions affect vernal pond construction. With an eye to basic landforms you should be able to make a vernal pond that looks and functions like a natural wetland.

Many vernal pond constructions are successful; however, a few fail to meet expectations. Generally, projects fail because the ponds do not hold water long enough for aquatic plants to become established and for aquatic animal larvae to completely develop. Building a pond that fails to hold water is generally due to permeable soils, a poorly constructed core under the dam, and failure to compact soil during construction. This chapter is designed to help you think through site selection, to introduce you to construction techniques, and to help you determine the best location for constructing a vernal pond.

## who can make a vernal pond?

Vernal ponds can be designed to fit into land parcels of most any size. They can make a positive addition to a school, visitor center, office complex, or your home landscape.

One need not be an engineer or biologist to make a vernal pond. However, depending on your experience, you may want to consult a professional. Professional wildlife managers have been establishing and restoring seasonal wetlands for many years and can be an excellent reference for the novice.

*This small vernal pond was built at the edge of the Prestonsburg Elementary School playground in Kentucky.*

A variety of techniques may be used to create a vernal pond. The complexity of this work often depends on the site and the desired size of the pond. The techniques range from hand tools, to blasting, to heavy equipment. Your familiarity and comfort in working with these techniques should guide you in determining if you want to do the work yourself or seek professional advice and service. Programs may be available that provide technical and financial assistance for constructing a vernal pond. You may want to contact a wildlife biologist employed by your state fish and wildlife agency or a district conservationist with the USDA Natural Resource Conservation Service for assistance.

*A thirty-year-old constructed vernal pond.*

*A natural vernal pond in Morgan County, Kentucky.*

## are permits needed?

Some communities require that you obtain a permit before constructing a wetland. The permit process may be designed to help insure that habitat for federally endangered and threatened and state rare species is not impacted by a project. The U.S. Army Corps of Engineers and state agencies may require a permit before you build a vernal pond in an area that is already a wetland. Permits may also be required if you plan to construct a dam in the floodplain of a stream or river. Vernal pond projects may fall under a general nationwide permit or a waiver may be granted from permitting agencies. It is recommended that you look into permitting requirements for your area in advance and obtain all necessary permits before starting a vernal pond construction project.

*This track-hoe is being used to make an ephemeral wetland. These machines are also used to drain natural wetlands.*

## know what to expect

Contact electric, gas, water, and phone companies to identify possible buried utilities on the location. This is especially important when digging near roads and schools and other buildings.

One must modify the landscape to make a vernal pond. The extent of modification depends largely on site selection and the desired size of the pond. Sometimes constructing a vernal pond may involve moving a considerable amount of soil. In those cases, heavy equipment such as a dozer or track-hoe may be the most efficient means to shape the new wetland.

*It will take time for plants to become established in and around this four-month-old vernal pond.*

Some people find the use of heavy equipment and the appearance of exposed soil unsightly and troublesome. Depending on climate, it often takes constructed wetlands about five years to "heal" and to develop a natural appearance. The most obvious concern is exposed soil that does not establish plants immediately. This can be unsightly, as well as an erosion concern. Seeding annual species such as wheat and applying straw for mulch can stop erosion and give a new wetland an attractive appearance.

*This four-year-old vernal pond contains a diversity of plants.*

## know the area

The opportunity to restore a vernal pond at the exact location where one once occurred is limited in most areas. However, it may be possible to return vernal ponds to the same region where they once occurred. Old aerial photographs can help identify the location of natural wetlands that once occurred in an area. More recent aerial photographs can help identify wetter areas that may be suitable for vernal pond construction. Talking to landowners and people who manage the land can yield valuable information about the size and shape of historic natural wetlands in your area. In general, it is easier and less expensive to create a vernal pond in an area that has soils that can be made to hold water without using a synthetic liner.

*This field may once have been a wetland, considering the present drainage ditch. The area could be made into a wetland today.*

## look for construction fill

When near developments such as buildings and roads, one may encounter low areas that have been filled with waste rock, gravel, concrete, asphalt, stumps, and logs. This mixture of construction debris is quite permeable, making it difficult to construct a wetland unless a synthetic liner is used. Use a shovel, post-hole digger, or a backhoe to test the soil for the presence of construction fill prior to building a wetland.

## avoid natural wetlands

Existing vernal ponds are difficult to identify during the dry season. Often a low, wet place will look like a good location to establish a new vernal pond. These locations should be carefully examined to make sure that they are not existing natural wetlands. Some clues that may alert you to the presence of a seasonally dry wetland include: dark stained leaves, caddis fly larvae cases, fingernail clams, aquatic snails, bright green sedges, and a lack of trees growing in the depression. These natural wetlands are most likely already providing habitat to many plants and animals.

The importance of protecting natural wetlands cannot be over emphasized. One should use care when selecting a location for a vernal pond so that habitat for federally endangered, threatened and state rare species is not adversely affected. Consider asking a biologist for help in selecting a suitable location.

*Dark stained leaves in an area with few trees often indicates an existing vernal pond during the dry phase.*

There may also be human-made features on the landscape that are functioning as vernal ponds. Motor vehicle tire ruts often provide the shape and compaction needed to make small, linear wetlands. Consider retaining these small wetlands in roads that are no longer driven. A disadvantage of a road rut wetland is that it becomes a deathtrap for amphibians when a vehicle drives through it during the breeding season.

*Vernal pond built on a closed road.*

Water bars used to stop erosion on roads may also become vernal ponds. A water bar is a small dam placed across a road to slow flowing water. Most water bars are made so that they do not trap runoff, but divert the water in small amounts to the side of the road. Placing a shallow dip in front of a water bar can make a small vernal pond that also helps trap sediment.

## cost considerations

Most natural vernal ponds occur on level areas. Building a vernal pond on level ground is easier and less expensive than building one on a hillside. An area with less than 3 percent slope (3-foot -change in elevation over 100 foot length) works best for construction.

If large trees are present, a small wetland may be located between the trees. It is possible to make a vernal pond in a tree gap as small as 15- by-15-feet with hand tools and a synthetic liner. Removing large trees from a wetland construction site is difficult and costly, and in general, not recommended.

Cost estimates for a variety of construction methods can be found in Chapter 4 - Reference Material.

## the surrounding landscape

A greater variety and number of species can be expected to use a vernal pond if it is built near other wetlands. Nearby wetlands provide a source of amphibians, reptiles, insects, and plants that can readily colonize a new vernal pond. A mosaic of wetlands best meets the habitat needs of species such as shorebirds and waterfowl. However, a variety of species will use a wetland that is built in most any location. Even isolated wetlands are known to provide habitat to rare species.

## staying away from conflicts

Other considerations in deciding where to build a vernal pond should include the long-term management and maintenance of the completed wetland. Avoid placing vernal ponds in areas where human and animal disturbance cannot be controlled. Excessive use by horses and cattle will damage and destroy vegetation, puncture synthetic liners, trample amphibian eggs, and disturb wildlife. Well-intentioned humans may also stock fish in vernal ponds, rendering them unsuitable for many species.

*Natural and constructed wetlands are often temptations for ATV riders.*

A vernal pond is a living ecosystem that is constantly changing and evolving. The pond you know today may look and function differently in 5 years. A vernal pond can fill up with sediment in only a few years if the surrounding landscape is bare soil, or may last for hundreds of years if surrounded by vegetation.

## the wet-dry cycle

Key to constructing a successful vernal pond is that it not only holds water but also dries up once in awhile. In general, 90 or more consecutive days of water are needed over the winter and spring to allow insect and amphibian larvae to develop. A shallow wetland with a limited watershed in a sunny location is likely to dry up every year and may not provide enough time for salamander and frog larvae to develop. However, a deep wetland with a large watershed in a shaded location may never go dry.

*The same vernal pond at various stages of drying - - May and October*

The following factors and their relationship to each other influence how often a pond dries up:

- **Water depth**
- **Annual precipitation and evaporation**
- **Soil permeability**
- **Watershed size (amount of water that runs into the wetland from surrounding land)**
- **Amount of sunlight**
- **Transpiration from trees, shrubs, and plants growing in and around the wetland**

## water depth

The factor that you can influence most is water depth. Making a pond too deep produces a wetland that holds water all year. One of the best ways to determine how deep to make a vernal pond is to examine other wetlands in the area. The best time to do this is in the fall or driest time of the year. Look to see if these wetlands have a small or large watershed. Identify if they are in the sun or shade and if the soil type is comparable to your area.

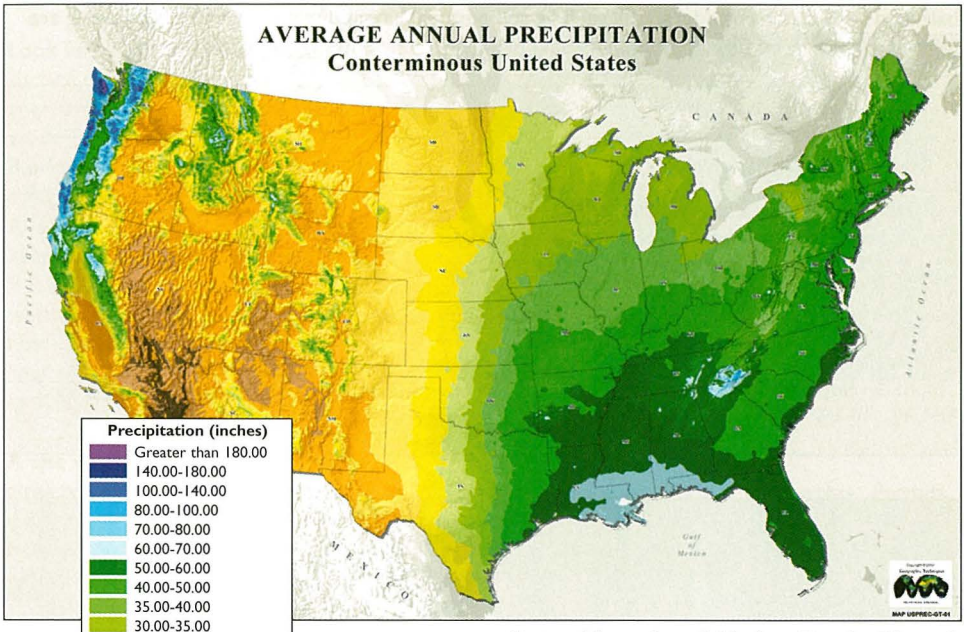
*This small wetland may never go dry; it is deep and surrounded by trees.*

If these characteristics are similar to the area you are considering for a vernal pond, then you have a good point of reference. Look for water lines along the shore and measure how far the water level dropped from spring. This can provide you with a good idea of how much evaporation to expect in an area.

## the kentucky experience

Rainfall averages 49 inches a year in eastern Kentucky. Wetlands 20 inches deep or less in sunlit areas or 15 inches deep or less in shaded areas with no watershed dry up most every fall.

*Constructed vernal pond on the Daniel Boone National Forest in the process of drying.*




*Prepared by and available from Douglas Norgord, Geographic Techniques, 203 W. Garfield Street, Mount Horeb, WI 53572-2126*

Information on average annual precipitation in your area may be obtained from the USDA Natural Resource Conservation Service: http://nationalatlas.gov/prismm.html. Personnel at your local USDA Natural Resource Conservation office may also have information on precipitation and evaporation rates for your area.

## soil permeability

Fine textured soil such as clay and silt loam holds water for a long time. Coarse textured soils such as sand and gravel allow water to seep into the ground, greatly reducing the amount of time a vernal pond made from these soils would contain water.

## watershed size

Unlike farm ponds, a large watershed is not necessary for a vernal pond. The vernal pond with many acres of water running into it may never go dry. A large amount of water entering a vernal pond with a large watershed may damage the vernal pond and prematurely fill it with sediment. Vernal ponds can be successfully built in areas with no watershed, filling with water just like a birdbath in your backyard.

## shade versus sunlight

Should a vernal pond be located in the shade or sunlight? Finding a site that provides both sunlight and shade allows maximum benefits; however, finding such a location may need to be balanced with other considerations such as soil permeability and watershed size. Following are factors to take into account when choosing between sunny and shaded locations.

| SUNNY | SHADE |
|---|---|
| Greater diversity in aquatic plants. | Aquatic plant diversity will be much lower. |
| Attractive to birds such as redwing blackbirds and common yellowthroat warblers for nesting. | Less likely to dry up annually compared to those exposed to sunlight. |
| Cattails may grow so densely that they crowd out more desirable plants. | May contain uncommon grass and sedge species adapted to shady wetlands. |
| Water warms earlier in the spring, promoting rapid development of amphibian larvae. | Falling or windblown leaves provide a rich environment for invertebrates, creating a food source for salamanders. |

*Vernal pond in full sunlight.*

*Shaded vernal pond with limited aquatic vegetation.*

## water table

Most vernal ponds are built on sites that do not have high water tables. High water table sites are uncommon in many areas. A way to test for a high water table is to dig a test hole down below the topsoil layer. Topsoil is dark colored and full of roots. A high water table is present when the hole fills with water seeping in from surrounding soil. If water seeps into the hole, you should wait to see if it rises near the surface. Some areas may have a seasonally high water table. Building on a site with a seasonally high water table results in a wetland that holds water during wet periods. The soil on a site with a seasonally high water table is generally quite permeable. Checking the elevation of water in the soil during different times of the year will provide a better idea of when the wetland would contain water. Personnel at your local USDA Natural Resource Conservation Service office may help you complete a soil test.

Look for crayfish burrows on the surface of the site being examined. If crayfish burrows are present, see if water is near the top of the burrow. Burrowing crayfish dig down into the ground until they reach water. A lack of water in a crayfish burrow indicates that a permeable soil layer is found deeper in the ground. A wetland built on such a site may not hold water without using a synthetic liner or the specialized construction techniques described in Chapter 3.

*A crayfish burrow that contains water near the surface is an indicator of a high water table.*

A site with a high water table may already be a wetland. Federal and state laws protect existing wetlands in many areas. Permits from both federal and state agencies are often required before you may be allowed to alter an existing wetland. Contact the U.S. Army Corp of Engineers and the appropriate state agency before making an ephemeral wetland on a site with saturated soils.

## test the soil

It is important to test the soil texture at the location where you would like to build a vernal pond. The best way to do this is to dig a test hole. A shovel, soil probe, post-hole digger, or backhoe may be used to dig a test hole. It is important that you dig several holes in the area and that they are deep enough to display the soil profile. It is best to test the soil at a variety of depths. Try to test soil texture to a depth of at least 4 feet. If you find that you are working in an area with silt loam or clay soils, you can make a vernal pond at a reasonable price; other soil textures will require mitigation and increased cost.

Use your hand to determine if the soil is clay or silt loam by attempting to make a two-inch long ribbon between your thumb and forefinger. You may need to add water to the soil sample to form a ribbon. If you can make a ribbon of soil at least two inches long, the site should hold water. The fine soil particles will keep water from leaking out of the wetland.

*Forming a ribbon indicates silt loam or clay texture soil that should allow a site to hold water.*

*Stream bank with silt loam on top of gravel.*

Look at the surface of the soil. Gravel indicates that the site is too porous to hold water. One cannot make a 2-inch long ribbon by squeezing gravel or sand between a thumb and forefinger, even if water is added to the soil sample. If you have no other choice than a site with sand or gravel, you may be able to use a liner to build a successful vernal pond.

One of the most troublesome circumstances involving soil properties and vernal pond construction is when you have silt loam on top of gravel. Gravel presents serious problems in making a pond, even when 8 feet below the surface. Ponds built where silt loam occurs on top of gravel will not hold water without special attention to the core. Information provided in Chapter 3 explains how to mitigate this problem, but it is important that you know before construction. One way to determine if silt loam exists on top of gravel is to look at a stream bank below the construction site. Look for an area where the soil is exposed on a vertical creek bank. The soil layers in the stream bank most likely represent those at the construction site. If the bottom of the creek is gravel you should test the soil on the potential wetland site with a backhoe.

## designing your vernal pond

You can make a vernal pond in a variety of sizes and shapes. Consider making the pond's edge irregular, round, or oval to help it blend into the natural surroundings. Natural wetlands have gradual slopes leading up to the water's edge. These gradual slopes are important to the emigration of fully developed amphibian larvae and, as the wetland dries, the mud exposed along the water's edge provides feeding sites to many shorebirds.

### the kentucky experience

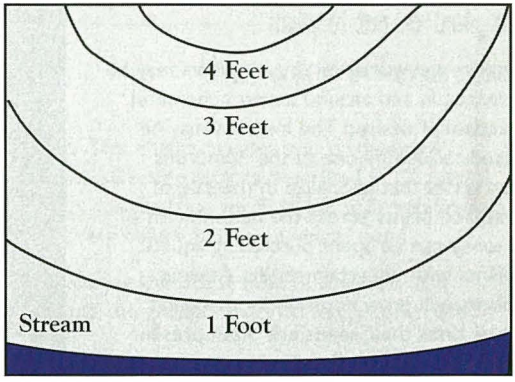
Natural vernal ponds located on ridge tops in eastern Kentucky average 60 feet in diameter (0.06 acres). In riparian areas in that same region the presence of drainage ditches and drain tiles indicates that much larger wetlands, over 3 acres in size, once occurred.

*A 0.6-acre vernal pond on the Daniel Boone National Forest.*

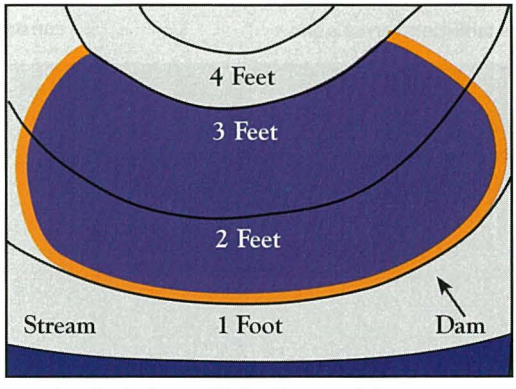
You will need to make a dam that traps runoff for the ephemeral wetland unless your site is level. The location and height of the dam can be marked with stakes or plastic wire flags. The maximum height of the dam is usually equal to the difference in elevation between the highest and lowest place on the construction site. The dam on an ephemeral wetland generally ranges from 1-to 3-feet high. The dam is placed along the lower edge of the project site.

You may want to use a hand-held or tripod-mounted survey level to measure slope on the construction site if it is larger than 0.25 acres in size.

*Using a level to measure slope on a vernal pond construction site.*




*This contour map shows a 4-foot-change in elevation over the construction site.*




*A 3-foot-high dam will flood most of the area.*

Make a sketch of where you want to construct the vernal pond and mark the pond outline on the ground with flags, chalk, or stakes. Drive a nail in a tree or set a stake in the ground at an elevation the same as the desired top of the dam. This benchmark will serve as a valuable reference during construction. Enlisting the help of someone with survey experience can help you design larger vernal ponds.

## protect your investment

To reduce erosion seed and mulch the exposed soil above the elevation of the water level in the new vernal pond. Winter wheat or annual rye provides excellent protection from erosion. These plants often germinate within three days of seeding and fortunately, are non-invasive. They live for less than a year; during that time, natural plants should colonize the area.

*Mulching exposed soil with straw can help stop erosion and promote plant growth.*

## to plant or not to plant

Native terrestrial or aquatic plants may be planted in and around a new ephemeral wetland if desired. The Internet may be used to identify one of the numerous nurseries that specialize in the sale of wetland plants across the nation. A lot of money can be spent purchasing aquatic plants with uncertain results. Aquatic plants will grow naturally in a wetland over time; their seeds are often present in the soil before flooding or are carried in by birds and the wind. However, planting showy native flowering species does improve the appearance of a newly established vernal pond.

*A variety of species were planted in this constructed vernal pond.*

## the kentucky experience

Research completed on the Daniel Boone National Forest by April Haight found that over 50 species of aquatic plants grew naturally in constructed vernal ponds within 5 years of establishment without planting.

*These aquatic plants grew naturally in a constructed vernal pond*

*The log these students are placing in a vernal pond will be used by turtles for basking and the green heron for hunting.*

## woody material

Natural vernal ponds located in forested areas often contain branches and logs. Placing branches and logs in and along the shore of a created vernal pond will greatly increase the number of wildlife species that use the new environment. Salamanders such as the spotted and Jefferson's will attach their eggs to tree branches that have fallen into the water. The marbled salamander lays its eggs beneath a log or under leaf litter in an ephemeral wetland during the fall when it is dry. The autumn rains help hatch the eggs, giving them a head start over other breeding amphibians. Emerging salamanders find protective cover in the logs near wetlands as they wait for suitable conditions to migrate from the water to the forest.

# Constructing a Vernal Pond

You should now be ready to construct a vernal pond. This chapter guides you through the construction phase by building on the planning and site selection factors described in Chapter 2. Chapter 3 helps you to select and implement the best construction method for your location. It is recommended that you read this chapter in its entirety before building a vernal pond.

The best time to build a vernal pond is in the fall or during the driest time of the year. It is difficult to move, pack, and shape wet soil. Waiting until the ground is dry to begin construction can save both time and expense.

There are three main ways to construct an ephemeral wetland. The first involves making a shallow depression in the soil to trap rainfall. The second involves making a shallow depression in the soil that will fill with ground water. The third involves using a liner to trap rainfall.

## choosing a construction method

Some people believe that one only has to dig a hole in the ground to make an ephemeral wetland. Too bad it isn't this simple. Most holes in the ground don't hold water. Natural, undisturbed ground is quite porous. It contains holes from roots, burrowing crayfish, and mammals such as the woodchuck. These holes need to be blocked to make an area hold water. Most ephemeral wetland construction techniques involve compacting the soil in a shallow depression to make it hold water. The soil is most often compacted with the tracks of a dozer.

Use the following key to identify the best construction method to use in building a vernal pond. The key uses information you obtain by testing the soil at the construction site.

### KEY TO CONSTRUCTION METHODS

A. Water near surface of soil.....B
A. Water not near surface of soil.....C

B. Location over 0.25 miles from people and dwellings.....BLASTING
B. Location closer than 0.25 miles from people and dwellings.....TRACK-HOE

C. Silt loam or clay soil present.....D
C. Silt loam or clay soil not present.....LINER

D. Silt loam or clay extends down to an impermeable layer.....DOZER
D. Silt loam or clay is on top of a permeable layer.....E

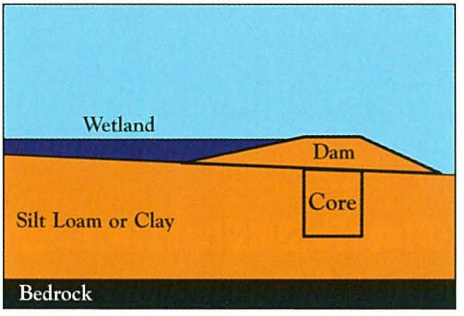
E. Small size wetland desired.....LINER
E. Large size wetland desired.....TRACK-HOE & DOZER

# Dozer Method

A dozer is used to make a shallow depression in the soil that will trap rainfall for a vernal pond. The soil in the depression must have low permeability for this technique to work. Silt loam or clay textured soils can be used to make a vernal pond with a dozer. For your project, try to hire a dozer operator with experience building ponds. Such an individual has likely learned how to make ponds hold water for the soil conditions found in your area. Checking references and visiting previous work sites will give you an indication of the operators level of experience.

*Remove and save topsoil.*

*Make a core under the dam location.*




*The core is made out of silt loam or clay.*

*Dozer moves soil in the core to eliminate holes.*

*Dozer moves and packs soil in the core.*

*Core is located under the entire dam.*

*The core will crush buried drainage tiles.*

*The core needs to go below this exposed crayfish hole.*

*Make the dam on top of the core.*

*Pack the dam in layers.*

*Make gradual slopes on the dam.*

*Spread topsoil on the bottom of the wetland.*

*Seed and mulch the dam.*

*Vernal pond constructed with a dozer.*

## remove and save the topsoil

Use the dozer to remove topsoil from the work area. Save the topsoil in a pile near the site to spread in the completed wetland. Topsoil should not be used in the dam or under the dam. Topsoil is dark in color and contains roots and organic material. It is porous and not suitable for making a dam. Topsoil often contains aquatic plant seeds. When re-spread in the bottom of a completed wetland it provides a rich substrate for aquatic plant growth.

## make a core under the dam

Use the dozer to construct a core beneath the dam. A core is critical to making a successful wetland. The core is an underground portion of the dam that is a barrier to water movement. It keeps water from leaving the wetland by traveling under the dam. A core should be made under the dam location before the dam is built.

Coring involves shifting and packing soil under the future dam. The core extends into the ground below the depth of holes made by crayfish, mammals, or tree roots. The core is usually made as wide as the dozer blade. It goes down to an impermeable layer of silt loam, clay, or rock. There is no need to remove soil from a core if is silt loam or clay. Permeable soil such as sand or gravel should be removed from the core, as they would allow water to pass under the dam. In some situations, an unexpectedly large amount of sand or gravel is found in the core during construction. It may be too costly to replace the permeable soil with impermeable soil. A decision would then need to be made to use a synthetic liner or to change work sites.

> Most wetlands fail because water leaks under the dam. You must compact the soil beneath the dam and remove any permeable material that may allow water to pass under the dam.

*Burrowing crayfish next to burrow.*

Using a dozer to make a dam on top of soil that has not been made into a core often results in a failed wetland. The coring process packs soil under the dam. Soil that is not compacted is quite porous. Most constructed wetlands that do not hold water have failed because of a bad core. A crayfish hole left intact under a dam may completely drain a wetland.

A dozer can make an excellent core. It is important to watch as the core is built. Look for holes at the surface. The dozer must dig down to the bottom of each hole. Some crayfish holes are 7 feet deep. Make sure that the entire hole is collapsed and packed. Stopping short of the bottom of the hole may allow a crayfish to re-dig the burrow, opening up a hole that will allow water to pass under the dam. Fortunately, not every wetland site has burrowing crayfish. A core may only need to be 2 feet deep if crayfish are not present. A core should be made even if a dam is not built. The core is made in these situations around the perimeter of the future wetland to keep water from seeping into the surrounding ground.

Most heavy equipment operators do not understand the importance of a core. Making the core often takes longer than making the dam for a wetland.

## build the dam

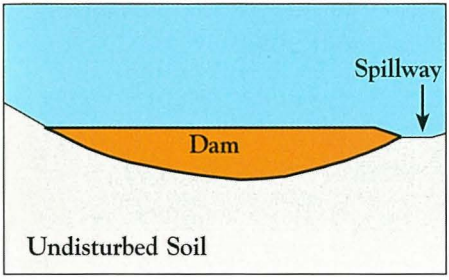
Use the dozer to build a dam on top of the core. Make the dam with a series of soil layers less than 6 inches thick. Pack the soil in each layer with the tracks of the dozer before adding the next layer. Use a hand-held or tripod-mounted survey level and rod to make sure that the top of the dam is level. This helps you avoid accepting low places in the dam. Water would flow over the dam in these low places, causing erosion of the exposed soil.

Make a gradual slope on the front and the back of the dam. A 10:1 slope (1 foot of rise for every 10 feet horizontal distance) looks natural. A dam with gradual slopes and a wide top holds up better to the frequent foot traffic experienced near schools and visitor centers. Such a dam is easier to maintain by mowing and is less likely to be damaged by muskrats.

*One-year-old vernal pond that blends into the landscape due to the dam being constructed with a gradual slope.*

## make a spillway

Making an ephemeral wetland with a dam over 3 feet high requires special attention to how water leaves the wetland. Water that flows over a dam may wash out the dam, causing a considerable amount of erosion. A spillway is used to protect the dam from damage. Overflow water can be made to leave the wetland over the spillway. The spillway is a wide, gradually sloped path of undisturbed soil located next to the dam that allows excess water to travel around the dam.




*Cross section of dam and spillway.*

*The spillway provides a path for water to leave the wetland.*

The spillway should be 6 inches to 1 foot lower than the top of the dam. The spillway is generally the width of one dozer blade. A narrow spillway will erode into a deep trench. Care should be taken to vegetate the spillway after construction. A grassy spillway will accommodate water leaving most wetlands. The spillway may need to be lined with rock if the wetland has a large watershed.

One should make the spillway after the dam is built. Use a hand-held or tripod-mounted survey level and rod to identify the lowest place in the dam. Set the elevation of the spillway 6 inches to 1 foot below the lowest place in the dam. Try to visualize how water will flow out of the wetland. You want it to follow the path of the spillway.

## install drainpipe

Installing a drainpipe in a vernal pond provides management options at a relatively low cost. A drain allows you to achieve a desired wet-dry cycle by intentionally drawing down water. You may easily remove unwanted fish species and complete repairs by opening the drainpipe.

PVC pipe that is joined together with gaskets should be used for draining ephemeral wetlands because glued joints may break under freezing conditions. Schedule 35 or Schedule 40 SDR PVC gasket pipe is readily available at plumbing supply stores at a reasonable price. PVC pipe is lightweight, easy to install, and does not leak or rust. A 6-inch-diameter pipe is large enough to drain most any ephemeral wetland. Install a drainpipe in the deepest part of the ephemeral wetland. During construction, the drainpipe is placed on top of the completed core just before the dam is built. The dam is built over the drainpipe to compact the soil around the pipe. Many pond construction manuals recommend that an anti-seep collar be placed around the drainpipe; these collars are unnecessary for ephemeral wetland construction.

A drainpipe can be modified to serve as a water control structure. One can attach a gasketed 90 degree elbow with a pipe extension to the inlet of the drainpipe. Water levels may be adjusted or drained by rotating the elbow and overflow pipe parallel to the bottom of the wetland.

*This PVC pipe serves as an overflow pipe when vertical; the stake provides support to the pipe.*

*The same pipe can be moved parallel to the ground to drain the wetland.*

## finishing touches

You may have extra soil left after building an ephemeral wetland. Spread the excess soil around the ephemeral wetland. You can taper the soil to blend into the surrounding landscape. Don't use the extra soil to make a "donut" shaped dam around the ephemeral wetland. Such a ring of soil can keep water run off from entering the wetland. It also looks artificial. Spread the topsoil in the bottom of the new vernal pond and shape the soil so that it blends with the landscape.

## Track-Hoe and Dozer Method

If you determine that you will be working on a site that has a layer of silt loam on top of gravel, you can make a small vernal pond by using a synthetic liner as described later in this chapter. However, if you want to make a large vernal pond, you will need to give special attention to building the core under the dam; a track-hoe is recommended. This is especially important if you are working in an area where crayfish are present. Crayfish will burrow down through the silt loam in the bottom of the wetland to the gravel. Rainfall will then follow the crayfish burrow to the gravel layer. Water will leak out of the wetland by following the gravel layer that extends under the dam.

Follow the steps outlined in the DOZER METHOD section to make a large vernal pond on a site that has silt loam on top of gravel. Then follow these additional steps to insure success when making the core.

(A) Use a track-hoe to dig a wide trench that will form the core. Dig the trench as wide as the blade on a dozer.

**(B) Dig the trench wide enough for a dozer to go down into the bottom for packing the soil.**

(C) Have the track-hoe remove the silt loam from the top of the trench and place it along the inside edge of the wetland.

**(D) Use the track-hoe to remove the gravel from the bottom of the trench and place it outside of the wetland. The gravel may later be used to make the backside of the dam.**

(E) Dig the trench down to an impermeable layer such as bedrock or clay. In some places you may need to dig down 14 feet to find an impermeable layer.

**(F) Use a dozer to fill the trench with silt loam soil. Pack the soil in the core trench well with the dozer. The goal here is to make an "underground" dam.**

(G) Construct the dam on top of the core.

### the kentucky experience

Vernal ponds over two acres in size have been made in eastern Kentucky where silt loam occurs on top of gravel.

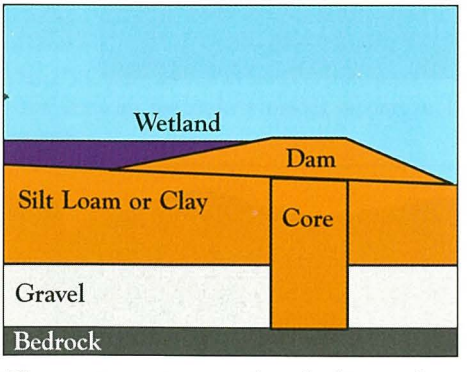
*Two-year-old wetland constructed in a site with silt loam on top of gravel. This core extends 12 feet down into the ground.*

*Track-hoe digs a trench down to bedrock to form the core.*

*As the trench is being dug, silt loam is placed inside the wetland; gravel outside the wetland.*

*Dozer fills the core trench with silt loam.*

*Dozer packs soil in layers to build a dam above the core.*




*The core prevents water from leaking under the dam.*

*Five-year-old wetland built with a track-hoe and dozer.*

# Liner Method

A liner is needed to insure that a wetland will hold water if the soil on a desired site consists of sand, gravel, or has buried fill from previous construction. Liners are expensive and you may need to limit the size of your vernal pond to stay within budget. Reminder: The soil on a site is most likely sand or gravel if you cannot make a ribbon that is two inches long between your thumb and forefinger.

## use a quality liner

It is difficult to make a wetland larger than 30 feet wide and 40 feet long with a liner. Liners are heavy and challenging to move into position. Commercial liners that are used for landfills work well for ephemeral wetlands. These can be made to most any size. Make sure that the liners you order are "fish grade" or "aquatic safe." These do not contain toxic chemicals that kill aquatic life. Do not use tarps or plastic drop cloths from the department store. These are thin and puncture easily. Synthetic liners are readily available from a number of sources. Liners made of EPDM (ethylene propylene monomer) that is 45 mils thick, or PCV (polyvinyl chloride) that is 30 mils thick, work well. These companies sell synthetic liners to companies as well as individuals:

**Fab-Seal Industrial Liners, Inc.**
42404 Moccasin Trail
Shawnee, OK 74804
1-800-874-0166
http://www.fabseal.com

**Just Liners, Inc.**
35507B Clearpond Road
Shawnee, OK 74801
1-888-838-4017
http://www.justliners.com

## protect the liner

You may need to sandwich a fabric pad under and over the liner to protect it from puncture by sharp rocks and sticks in the soil. The fabric pads also keep tree roots from penetrating the liner. These fabric pads are called "geo-textile" or "geo-pads." They are similar to a strong synthetic blanket and may be purchased from the same companies that sell synthetic liners. Research conducted on PVC liners used in landfills indicates that an ephemeral wetland constructed with a synthetic liner that is covered with soil (described above) should last for 30 years or more.

Here are the steps to follow when using a liner to make a vernal pond:

**(A) Use a dozer to dig a shallow depression in the soil. Make the depression 6 to 8 inches deeper than the desired water depth so that soil can later be placed over the liner. A small dam may need to be built along a low end of the site to make the outer edge of the wetland level.**

(B) Place a geo-textile pad in the depression. The geo-textile pad protects the liner from puncture by sharp rocks or sticks.

**(C) Place the synthetic liner on top of the geo-textile pad.**

(D) Place another geo-textile pad on top of the synthetic liner.

**(E) Anchor the top edges of the synthetic liner and geo-textile fabric pads with wire stakes or large nails with washers placed approximately 24 inches apart. The stakes keep the liner from being pushed down into the depression when it is being covered with soil.**

*A dozer makes a shallow depression in the soil.*

*A liner is placed in the depression.*

*The liner is protected on both sides by geo-textile fabric.*

*The liner is secured with stakes.*

*A dozer is used to cover the liner with soil.*

*Two-year-old vernal pond made with liner.*

## cover the liner with soil

Use the dozer to cover the liner with 6 to 8 inches of soil. The dozer will not harm the liner as long as it rides on top of soil that it is pushing over the liner. Avoid turning the dozer while on top of the liner. Turns will tear the liner. The soil protects the liner from being punctured by deer and horse hooves. It also protects the liner from sunlight deterioration and provides a substrate for plant growth. Amphibians and insects may spend the winter on the bottom of the wetland in the soil placed over the liner. Seed and mulch the exposed soil to reduce erosion.

## using hand tools to install a liner

It is possible to dig a vernal pond by hand with a shovel. This may be a tempting option if you have access to inexpensive labor such as students or relatives. However, a hand-dug wetland may not hold water due to low compaction. Consider using a liner in a hand-dug wetland to insure success. To make a large vernal pond with a liner, use a dozer or backhoe to move the greater quantity of soil.

*This group of Boy Scouts hand-dug two 10-foot diameter vernal ponds in one day.*

*They removed sharp sticks and rocks.*

*After placing the liner, they covered it with soil.*

*They seeded and mulched the exposed soil.*

*Four months later...*

## plastic tubs

Preformed molded plastic tubs used for landscaping can be used to make a very small vernal pond. A plastic tub may be the only way to make a vernal pond on a site with sharp, rocky soil. Most of these tubs are made with vertical sides that should not be used. Only tubs with gradually sloped sides should be used to make vernal ponds. Tubs with vertical sides can become deathtraps for amphibians, reptiles, and mammals as water levels drop. It is possible to use rocks, soil, or galvanized wire mesh to make an escape ramp for animals to climb out of the water. However, these escape ramps require regular maintenance to keep them functional.

## clay liners

You may hear a suggestion to place a layer of clay or bentonite in the bottom of a leaking constructed wetland to make it hold water. This technique rarely works. Wetlands leak for a variety of reasons. The most common is that water from the wetland is going under the dam. Placing clay in the bottom of a wetland where water is seeping under the dam may provide a short-term fix; however, all it takes is one crayfish or muskrat to dig a hole in the clay and the wetland will leak again. A synthetic liner sandwiched between two geo-textile pads and covered with 6 inches of soil provides a more permanent fix for a leaky wetland. However, a layer of clay may repair a leaky wetland built from sandy soils where burrowing crayfish are not present.

*Small vernal pond hand-dug in clay soil by iron ore miners in 1850. (Teresa Brasfield photo)*

*Waterfowl find valuable food in this 6-year-old ephemeral wetland where annual plants are inundated by fall rain.*

# High Water Table Sites

Making a shallow depression in the soil that fills with ground water often results in a vernal pond on a location with a high water table. Working in saturated soils takes some ingenuity. It is easy for an operator to get heavy equipment hopelessly stuck on these sites. There are two proven techniques for building vernal ponds on areas with water near the surface. The first involves heavy equipment, the second explosives.

## track-hoe method

A track-hoe is an effective way to make a small ephemeral wetland on an area with saturated soil. An experienced operator can move the track-hoe into and out of soft areas where a dozer would get stuck. A contractor needs a somewhat open area for operating the track-hoe as the large boom and bucket swing widely, making it difficult to avoid hitting adjacent trees.

*Track-hoe making a vernal pond in a wooded area.*

*This vernal pond was built with a track-hoe on a site with a high water table.*

### the kentucky experience

A track-hoe can make over 20 small wetlands a day if sites are near one another.

*Two-year-old vernal pond constructed with a track-hoe.*

Here are some steps to follow when using a track-hoe to make an ephemeral wetland:

**(A) Determine how deep you would like the vernal pond.**

(B) Mark the perimeter of the vernal pond with plastic ribbon or wire flags.

**(C) Use a track-hoe to dig a hole for the vernal pond.**

(D) Slope the sides of the depression so that the wetland appears natural.

**(E) Seed and mulch exposed soil to reduce erosion.**

## blasting method

Explosives have been used to make ephemeral and permanent water wetlands for years. The technique can be used successfully in areas that cannot be reached by heavy equipment. Blasting is relatively inexpensive and results in a natural appearing ephemeral wetland.

Contact a licensed blaster if you are interested in using this technique. A licensed blaster may legally purchase, transport, store, and use the explosives needed to make an ephemeral wetland. You may find the name of a licensed blaster by looking in the Yellow Pages under "explosives." You may also phone an explosives distributor and ask for the name(s) of licensed blasters who work in your area. The International Society of Explosives Engineers (http://www.isee.org/) is also a good place to ask for help. The USDA Forest Service maintains a cadre of certified blasters who are available to help on National Forest System land. The forest blaster or regional blasting examiner would direct the use of blasting to establish wetlands in a national forest.

The explosives method may be safely used if a site is more than one-quarter mile from people, homes, utility lines, and other improvements. The actual blast may launch rocks and debris a considerable distance.Individuals with the Missouri Department of Conservation found that it takes a much greater quantity of explosives to make a wetland when the ground is frozen.

Water gel explosive works well to make a vernal pond in wet areas. Water gel explosive is readily available from companies that distribute explosives. A commercial mix of ammonium nitrate fertilizer and fuel oil (AN/FO) may also be used. AN/FO is more difficult to use than water gel as it must be kept dry up to detonation, but is the lowest priced explosive available for making a vernal pond.

Here are steps to follow when using explosives to establish a vernal pond:

(A) Determine how deep you would like the wetland.

(B) Mark the perimeter of the future wetland with plastic ribbon or wire flags.

(C) Enlist the help of a licensed blaster to design and implement the project.

(D) When blasting, make sure people and structures are a safe distance away from your activities.

(E) Set the AN/FO in hand-dug holes where you would like the vernal pond. Place the AN/FO in plastic bags. The top of the bag should be even with the surface of the ground.

(F) Seed and mulch exposed soil after detonation. There is no need to slope the sides of the new wetland. The loose soil will settle and appear natural in a few years.

*AN/FO is placed in a shallow hole.*

*A licensed blaster detonated the AN/FO.*

*Site immediately after blasting.*

*Site six years later.*

## Maintenance

Constructed ephemeral wetlands should be inspected at least once a year. Visiting them more often will tell you if they contain water as planned. Examine the dam to see if water has been flowing over it, which can cause erosion. You may need to clean branches and logs from the spillway so that excess water may continue to flow around the dam.

Muskrats, dogs, and woodchucks can dig holes in a dam. Holes that cause the wetland to leak are best repaired with a backhoe. The dam itself should be mowed once a year to control trees and shrubs, as their roots can weaken the dam and cause it to leak.

*Dense growth of cattails in a 3-year-old vernal pond.*

An inspection will identify whether or not all terrain vehicles or livestock are damaging the wetland. An inspection may also identify dense cattail growth that you may want to reduce. Muskrats may eventually control cattails in ephemeral wetlands over one-half acre in size. Should cattails grow too thick in a small vernal pond, you should be able to control them by simply hand-pulling. Cattails may be controlled in a larger wetlands by removing the water for two consecutive summers or by mowing when the site is dry.

## Sources of information

**Here are some sources of information about constructing vernal ponds, the species that use them, and how to teach students about wetlands:**

*This vernal pond is 8 years old.*

**Kenney, Leo P. and Matthew R. Burne.** 2000. A Field Guide to the Animals of Vernal Ponds. Massachusetts Division of Fisheries and Wildlife, Natural Heritage & Endangered Species Program & Vernal Pool Association, Route 135, Westborough, MA 01581. (508) 792-7270 ext. 200. **http://ww.state.ma.us/dfwele/dfw/dfwnhes.htm** or **http://www.vernalpool.org/**.

**Kenney, Leo P.** Diving Into Wicked Big Puddles, An Educator's Resource Kit for the Study and Teaching of Vernal Pool Ecology. The Vernal Pool Association, Reading Memorial High School, 62 Oakland Road, Reading, MA 01867. **http://www.vernalpool.org**.

**Kingsbury, Bruce and Joanna Gibson.** 2002. Habitat Management Guidelines for Amphibians and Reptiles of the Midwest. Partners in Amphibian and Reptile Conservation (PARC), 57 pp. **http://wwww.parcplace.org**. A web-based version of this guide is available at: **http://herpcenter.ipfw.edu/**.

**Maine Citizen's Guide To Locating and Documenting Vernal Pools**. August 1999. Maine Audubon Society, P.O. Box 6009, Falmouth, ME 04105 (207) 781-2330.

**Midwestern Ephemeral Wetlands.** Environmental Protection Agency **http:/herps.ipfw.edu/wetlands/ephemeral/**.

**Project WET.** 1995. K-12 Curriculum and Activity Guide. The Watercourse and the Council For Environmental Education, 201 Culbertson Hall, Montana State University, Bozeman, Montana 59717-0570. **http://www.montana.edu/wwwwet**.

**Ripple, Karen L. and Edgar W. Garbisch.** 2000. POW! The Planning of Wetlands, An Educator's Guide. Environmental Concern Inc., P.O. Box P., 201 Boundary Lane, St. Michaels, Maryland 21663. **http://www.wetland.org**.

**Szafoni, R.E., C.A. Phillips, S.R. Ballard, R.A. Brandon, and G. Kruse.** 2002. Illinois landowner's guide to amphibian conservation. Illinois Natural History Survey Special Publication 22. iv + 26pp.

**Thompson, Alice L. and Charles S. Luthin.** 2000. Wetland Restoration Handbook for Wisconsin Landowners. Wisconsin Department of Natural Resources, P.O. Box 7921, Madison, WI 53707.

**USDA** 1997. Ponds-Planning, Design, Construction. Agriculture Handbook Number 590. Natural Resource Conservation Service. 85pp.

**USDA** 2000. Guide for using, storing, and transporting explosives and blasting materials. Forest Service. Technology and Development Program, 6700 Safety and Health, Chapter 10: Specialty Blasting. August 2000. 0067-2803-MTDC.

**WOW! The Wonders of Wetlands, An Educator's Guide.** 1995. Environmental Concerns Inc. and The Water Course, P.O. Box P, St. Michaels, MD 21663-0480.

# Vernal Pond Construction, Supply, & Budget Needs

(as of 2002)

### Vernal Pond, 60-foot diameter, dozer method:

| | |
|---|---|
| A) Dozer contract (5 hours @ $60/hour) | $300.00 |
| B) Grass seed for exposed slopes (20 lbs. @ $1.20/lb) | 24.00 |
| C) Winter wheat for exposed slopes (1-50lb. bag @ $6.50/bag) | 6.50 |
| D) Straw for mulch (15 bales @ $3.75/bale) | 56.25 |
| | **Total: $386.75** |

### Vernal Pond, 30 by 40 feet, liner method:

| | |
|---|---|
| A) Dozer contract (5 hours @ $60/hour) | $300.00 |
| B) Synthetic liner (PVC, 30 mil): 1,200 square feet @ $0.38/square foot | 456.00 |
| C) Geo-textile fabric to place above and below synthetic liner: 2(1,200 square feet @ $0.25/square foot) | 600.00 |
| D) Wire stakes to anchor top edge of liner (50 @ $0.25/each) | 12.50 |
| E) Grass seed for exposed slopes (20 lbs. @ $1.20/lb) | 24.00 |
| F) Winter wheat for exposed slopes (1-50lb. Bag @ $6.50/bag) | 6.50 |
| G) Straw for mulch (15 bales @ $3.75/bale) | 56.25 |
| | **Total: $1,455.25** |

### Vernal Pond, 60-foot diameter, track-hoe method:

| | |
|---|---|
| A) Track-hoe contract (5 hours @ $90/hour) | $450.00 |
| B) Grass seed for exposed slopes (20 lbs. @ $1.20/lb) | 24.00 |
| C) Winter wheat for exposed slopes (1-50lb. bag @ $6.50/bag) | 6.50 |
| D) Straw for mulch (4 bales @ $3.75/bale) | 15.00 |
| | **Total: $495.00** |

### Vernal Pond, 30-foot diameter, explosives method:

| | |
|---|---|
| A) AN/FO, boosters and cord | $250.00 |
| B) Licensed blaster fee | 250.00 |
| B) Grass seed for exposed slopes (15 lbs. @ $1.20/lb) | 18.00 |
| C) Winter wheat for exposed slopes (0.5-50lb. bag @ $6.50/bag) | 3.25 |
| D) Straw for mulch (3 bales @ $3.75/bale) | 11.25 |
| | **Total: $532.50** |

### Vernal Pond, 2-acre size, dozer method:

| | |
|---|---|
| A) Dozer contract (40 hours @ $60/hour) | $2,400.00 |
| B) Grass seed for exposed slopes (50 lbs. @ $1.20/lb) | 60.00 |
| C) Winter wheat for exposed slopes (3-50lb. bags @ $6.50/bag) | 19.50 |
| D) Straw for mulch (50 bales @ $3.75/bale) | 187.50 |
| E) Fertilizer for dam (4-50lb. bags @ $6.50/bag) | 26.00 |
| F) Lime for dam (20-50lb bags @ $1.20/bag) | 24.00 |
| G) Drainpipe (52 feet @ $1.10/foot) | 57.20 |
| H) 90 degree elbow for water control structure | 4.50 |
| | **Total: $2,778.70** |

Two-year-old constructed vernal pond.

Natural vernal pond.
(Teresa Brasfield photo)

Discover how to make an ephemeral wetland
that looks and functions like a natural wetland.